

2.0 Risk Analysis Overview

2.1 Pipeline Risks

In the public perception, a disaster involving hazardous materials is reportedly high on a list of concerns (FEMA, 1989). However, catastrophic releases, i.e., those that actually harm more than a few people at a time, are actually relatively rare events.

Pipelines are designed, built and operated according to government and industry standards specifically developed to ensure their safety. The federal Office of Pipeline Safety (OPS) has jurisdiction for interstate natural gas and hazardous liquid pipelines. The State of California has jurisdiction for intrastate pipelines (i.e., those operating within state boundaries). Federal rules may be adopted by a state. For example, The California Public Utilities Commission (CPUC) regulates natural gas pipelines under 49 CFR, Part 192, and CPUC General Order No. 112-E (CPUC, 2000). California's Office of the State Fire Marshal (SFM) regulates intrastate hazardous liquid transportation pipelines. Other state agencies that may also be involved in pipeline regulation and/or be a source of information include the California Department of Conservation, Division of Oil, Gas and Geothermal Resources, and the California Department of Fish and Game, Office of Spill Prevention and Response.

The above entities may be contacted for information and/or to file a complaint for violation of requirements of Education Code Section 17212.2. This code section provides that a school district may make a written request upon any entity for information necessary or useful to assess and determine the safety of a proposed school site or site expansion, including pipeline information. The entity shall, within 30 days of receipt of the written request, either provide the requested information, identify available public information or an available report, or provide justification as to why the information is not being provided. The school district may file a complaint with the appropriate regulatory or legislative body for violation of the requirements, which may then appoint a representative to work toward informally resolving the complaint.

Further notes on the state agency roles and addresses for contacts are presented in the Appendices section, Appendix G.

The concern for pipelines arises from risks associated with their use to transport hazardous materials, some at relatively high pressures. The risk from a pipeline is the combination of the probability of its failure and the severity of the consequences that result. The classical mathematical representation of risk is,

$$\text{Risk} = \text{Event Probability (or Frequency)} \times \text{Severity of Consequences (or Impacts)}$$

If a specific adverse consequence is defined, then risk can be represented by the probability or chance that the specified consequence will occur within a specified period of time. The probability is driven by a number of factors, from deterioration, such as corrosion, to damage from outside forces, such as a third party digging into a line, for example. The consequences depend on the nature and quantity of the substance released if a pipeline fails and the separation distance between the release and people.

An estimate of the probability of such failures can be derived from historical data on similar systems. Such data are available in public records of incident reports. The consequences of failures can be estimated based on historical and experimental evidence. These data are combined in the risk analysis to provide a quantitative estimate of the risk to people within specified distances of a pipeline.

2.2 Pipeline Risk Analysis Factors

Factors for a risk analysis involve a number of variables associated with the pipeline itself and its location relative to a proposed school site. The variables relate to the probability and consequences of a release. A listing of such factors is presented in Appendix A of the Appendices section.

In general, key factors related to the probability of release include:

- Size, age, type and operating pressure of the pipeline;
- Product transported; and
- Location of the line, relative to natural and man-made threats.

Key factors related to consequences of release are:

- The same three as above for probability;
- Proximity of the line to a proposed school site;
- The design of the school site and structures thereon;
- Meteorological conditions; and
- Local terrain, topography and land use.

2.3 Pipeline Risk Analysis Methods

Two basic classes of risk analysis methods are qualitative and quantitative methods. Pipeline operators use both methods in making pipeline rehabilitation and repair decisions. An operator uses risk analysis for ranking individual locations and lengths of pipe along a pipeline (segments), in relative terms, as a tool in establishing priorities for inspection, testing and repair actions. This concept of risk ranking is applied in the new federal integrity management

regulations and expanded to include decisions regarding specific risk control measures, both for preventing and mitigating accidental releases of pipeline product.

2.3.1 Qualitative Methods

Qualitative methods may focus only on relative consequences or assess the probability and consequences in relative terms, such as high, medium and low. For example, a vulnerability zone can be estimated for a worst-case release of a substance. If the school site lies outside the vulnerability zone, no further analysis is required. Qualitative approaches combining probability and consequences often use numerical scoring methods to generate a relative risk ranking of various pipeline segments, of various lengths, along a pipeline route. Pipeline operators sometimes use these methods to set priorities for rehabilitation, repairs, inspection and testing of specific line segments. These methods define a number of risk factors, each of which is assigned a numerical value. The factors are mathematically combined, usually by addition, to yield a numerical score value for each predefined segment length of pipeline. In this manner, segments can be ranked and grouped according to relative risk associated with a leak or spill. The various methods in commercial use each deal with both the probability and consequences of leaks or spills in such a manner that the ranking reflects a total risk rather than just the likelihood of a pipeline failure. (e.g., Muhlbauer, 1996, Bass Trigon Software, 2002).

2.3.2 Quantitative Methods

A quantitative risk analysis method is used in this Protocol. Quantitative methods seek to estimate numerical event frequencies or probabilities, for a specified time period, associated with specific, measurable consequences. These methods often express risk in terms of the probability of a specified outcome. For example, the risk of fatality from a pipeline accident can be expressed as the annual probability that a fatality might occur. This is the basis of the Individual Risk and Population Risk Analysis focus of this Protocol, as discussed later.

Two basic types of quantitative methods are: actuarial methods that estimate the probability of future events based on the historical data on the occurrence of similar events; and synthesis methods that estimate the probability of an event from the probabilities of contributing events through appropriate mathematical calculations. Actuarial methods are most appropriate where the events are relatively frequent in a relatively uniform population. The synthesis methods are most appropriate for rare events where little experience is available. A third type of predictive quantitative method applies when the actual physical conditions associated with a pipeline are known (such as the extent and activity of corrosion or cracks). Such data are not typically available to a LEA for analysis.

The approach used in this Protocol is a combination of an actuarial and synthesis method based on historical data for various events contributing to the ultimate outcome, which in this case is the risk of fatality from a flammable product release from a pipeline.

Risk analysis consists of identifying threats and their consequences, then evaluating them for decision-making. Risk evaluation combines the likelihood or probability of an event with an estimate of the predicted consequences as a measure of risk. Risk evaluation allows threat prioritization and for better risk management planning purposes. In the context of pipelines near proposed school sites, pipeline risk evaluation examines the probability of harm to people at the school site. The harmful consequences of a pipeline failure can include injuries or fatalities from exposure to thermal radiation from fire, explosion blast pressures or airborne toxic chemical concentrations above safe thresholds.

Risk analysis for accidental releases of hazardous substances is a standard practice in the process and transportation industries, which comprise pipeline operations. Government regulations of the U.S. Environmental Protection Agency (EPA); U.S. Department of Transportation (DOT)-Pipeline and Hazardous Materials Administration (PHMSA)-Office of Pipeline Safety (OPS) and even the Occupational Health and Safety Administration (OSHA), implicitly or explicitly require some form of hazard analysis or risk analysis for accidental releases of hazardous materials. There are also professional bodies, such as the American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS) that research and promote practices for enhancing risk analysis for hazardous materials.

The general steps in a pipeline risk analysis are as follows:

- Data Compilation – The first step is to compile all pertinent data for the risk analysis. This includes the location and characteristics of the pipeline and the school campus site of interest. See Section 4 for details.
- Hazard identification – The pipeline system must be characterized in sufficient detail to formulate potential accident scenarios and to permit subsequent evaluation of accident probability, likely release amount, and nature and magnitude of resulting impacts.
- Probability analysis – Probability analysis determines the likelihood of an event, expressed in relative (typically referred to as likelihood) or quantitative terms (typically referred to as probability).
- Consequence analysis – Consequence analysis examines the potential physical impacts and derivative consequences (e.g., harm to people, or the environment) of a pipeline failure and accidental release of product.

- Risk evaluation – Risk evaluation creates a numerical combination of both the probability of an event and its consequences.
- Risk control – Risk control consists of prevention and mitigation measures respectively to reduce the probability that a release of pipeline product will occur and to minimize the impacts of any release that might occur.
- Reporting – When the risk analysis is completed, results are reported to CDE. The report contains information on the campus site, pipeline, method, data and assumptions and results.

2.4 Causes of Pipeline Failure

Understanding the events that could lead to a pipeline failure and product release comprises the first step in a risk analysis, hazard identification. Based on historical experience, the main causes of pipeline leaks or ruptures can be classified as (other classifications are possible):

- Corrosion (internal and external);
- Excavation damage;
- Natural forces (e.g., ground movement, flooding displacement, etc.);
- Other outside forces (e.g., fire or explosion near the pipeline);
- Material and weld defects;
- Equipment and operations (e.g., such as overpressuring an inadequately protected system through inappropriate operating settings); and
- Other (i.e., not included above or unknown).

These categories have been used in the U.S. Department of Transportation Accident Report forms (RSPA 7000-1, 7100.1, 7100.2). Changes have been made and the current DOT accident forms provide multiple subcategories, resulting in more than 20 different classifications of causes. Further discussion of the above listing is presented in Volume 2 of this Protocol.

2.5 Pipeline Risk Evaluation

The fundamental risk calculation for the CDE risk evaluation process is the estimated Individual Risk (IR). IR is defined here as is the annual probability of fatality resulting from a pipeline failure and product release for an individual at the property line or boundary between the usable and occupied portion of a school site and any unoccupied and non-usable portion of the property. The IR probability is determined for a defined level of occupancy (fraction of time at the school site) and outdoor exposure (fraction of time outdoors at the school site). It is assumed that the individual occupies the specified location for which the IR is evaluated. Individual risk

depends on the characteristics of the pipeline and location conditions. This definition is consistent with the definition of individual risk provided in the technical literature dealing with accidental releases of hazardous substances (CCPS, 1989). An example calculation is provided along with guidance on preparing IR estimates in Section 4 of this Volume.

IR value from the analysis can be compared with established risk criteria to make decisions on the suitability of a given site or to compare multiple sites. This is demonstrated in a numerical example in Section 4. The Protocol defines an IR criterion established by CDE.

2.6 Risk Control through Prevention and Mitigation

Risk control measures reduce the probability or consequence of a pipeline failure. Title 49 CFR, Part 192 and other codes of practice broadly define prevention and mitigation measures for pipeline leaks. An operator's practices must conform to the minimum requirements of applicable federal or state regulations. In practice, most pipeline operators exceed these requirements.

2.6.1 Prevention Measures

Prevention measures are used to control risk by reducing the likelihood of a risk event occurring. Traditionally, codes, standards, regulations, and an operator's own good practices comprise prevention activities. Specific prevention activities generally focus on specific cause(s) of pipeline failures. For example, prevention measures associated with excavation damage include pipeline markers, patrols, and One-Call notifications.

Most prevention measures are the responsibility of the pipeline operator. Some are implemented during the design and construction of the pipeline, ensuring that the pipeline meets the specifications and requirements associated with its intended operation. Other prevention measures are incorporated into the day-to-day operations of the pipeline.

For a LEA, activities aimed at preventing pipeline incidents are somewhat limited. The LEA should participate in local planning discussions to understand where existing pipeline systems are in relation to school properties or where new systems are proposed.

2.6.2 Mitigation Measures

Mitigation measures are pre-engineered systems, procedures and practices that reduce the consequences of a pipeline product release, should a release occur. Emergency preparedness and emergency response plans are one of the most basic elements of mitigation. Some mitigation measures are common to all pipelines. Some depend on whether the line is a gas or liquid pipeline and whether the issue is product flammability, toxicity or both. Emergency preparedness and

response is a joint responsibility of the pipeline operator and of community support services such as fire departments and medical facilities.

As with prevention measures, many of the mitigation activities are the responsibility of the pipeline operator. Mitigation measures from an operator include such things as release detection and shut-off of product flow; rapid response to a release site; and adequate training to support the capabilities. For liquid pipelines, mitigation methods include procedures, and less commonly, pre-engineered systems for release diversion and capture into controlled drainage and containment areas.

More options are available for a LEA's role in mitigation activities. The LEA can have a role in developing adequate and appropriate emergency response plans and can implement periodic emergency response drills. The use of a risk analysis during the siting phase for new schools or school expansions provides a means for comparing risks associated with different options. During design and modification, measures can be implemented to minimize exposure to pipeline product releases. In some cases, it may be possible to quantify the effects of mitigation measures. However, when not quantitative, the professional opinion of the risk analyst is required to indicate if the effects of the mitigation measures will result an acceptable reduction in risk.

2.7 Limitations of the Method

Numerous factors affect the risks associated with pipeline failures. Information on all the factors will typically be incomplete. Assumptions and default values will be required for some of the input data requirements. This necessarily limits the accuracy of the risk estimate for a specific length (segment) of a pipeline. It is especially difficult to determine the probability associated with a specific short segment of pipe. The relationship between factors that affect the likelihood of failure and the failure rate remains an area of ongoing industry interest and research. Relative risk models have been developed that can be used to adjust generic failure rate data to account for specific local attributes in a pipeline system. However, this information is typically proprietary to the pipeline operator and is not generally available to a LEA. Therefore, it must be recognized at the outset, that the risk values determined using this Protocol are, in fact, estimates. The probability estimate for the failure of a given line segment is a statistical probability that may differ from the actual value for a given segment. In spite of this uncertainty, CDE has determined that the approach taken is reasonable within the context for which the Protocol was developed and for which the results will be used.

To reiterate, the goal of the Protocol is to provide a standard and consistent basis for achieving a "reasonable" estimate of the pipeline risk at school sites. Technical rigor and level of detail had to be balanced against the resources that could be allocated by a LEA and the need

for sufficient detail and rigor for the CDE evaluation at hand. The approaches used in other government agencies in similar types of evaluations and considerations provided the philosophical backdrop to the approach used in this Protocol.

Risk analysis cannot predict future events; it can only estimate the *chance* of specified events.